<u>Savings Formulas</u>

Foreword

Please note that ElectroFlow performance results in two types of savings: **Tangible**, and **Intangible**. Both of which are presented in the proposal. However, when we speak about Return On Investment (ROI), and Payback, we refer to Demand(KW), and Energy Consumption(Kwh) savings **ONLY**!

The accurate and scientific savings calculations are performed based on the following:

1. That we base our analyses on the following:

A. Actual measurements taken at the facility, such as voltage, current, harmonics, and power factor; along with their respective fluctuations.
B. Data collected, such as: transformer size, impedance, number and size of the cables, hours of operation, percentage of operation and so on.
C. Copy of their past 12-month electric bills, to establish as their load profile, and the base for comparison.

2. That the main factors contribute to the said savings are:

1. Voltage improvement and stability
2. Three-phase balancing
3. Harmonics mitigation
4. Power Factor improvement
5. Surges and transients

3. That following collection of the above data and information. We simulate a model for their electrical distribution and the load using a comprehensive multi-column, and multi-row matrix computer program. Such a computer analysis calculates the symmetrical as well the asymmetrical components for that purpose. Subsequently, incremental savings analysis will be applied cumulatively, based on the facility's load profile. Resultants of the said analyses will then be presented in the form of savings profile and financial considerations for the economic justification.

The said process is comprehensive and requires millions of data points. It is extremely difficult, if not impossible to extract each and every one of those values, as one can imagine. Though for all practical purposes, the most common discrete formulas used for the said analysis are provided as an indication for the said process.

The following are the main contributing factors for the savings analysis:

1- Rapid fluctuations of KW demand due to load behavior. Namely, voltage imbalance, voltage fluctuations, over/under voltage conditions. We must calculate for symmetrical components, as well as asymmetrical components:

A. Symmetrical Components-

$$KW = \frac{\sqrt{3} \times V \times I \times \cos\theta}{1000}$$

B. Asymmetrical Components-

$$a = e^{j2\pi/3} = -\frac{1}{2} + j\frac{\sqrt{3}}{2}$$

$$V_a = V, V_b = a^2V, V_c = aV$$

$$V_{ab} = V_a - V_b = (1 - a^2)V$$
$$V_{bc} = V_b - V_c = (a^2 - a)V$$
$$V_{ca} = V_c - V_a = (a - 1)V$$

Where, Kw must be calculated with respect to each value.

2- Three-phase imbalance- It is outlined in the measurements taken which may be asymmetrical or imbalanced, i.e., with unequal magnitudes or with phase displacements not equal to 120°. The voltage drop due to resistance and self- and mutual inductance in any conductor of a group of long, parallel, round, non-magnetic conductors forming a single-phase or three-phase circuit, and with one or more conductors connected electrically in parallel will cause currents to be imbalanced, and, in addition, the arrangement of the conductors will be asymmetrical. Namely, negative voltage sequence, circulating currents and the related asymmetrical components losses. Hence, we must calculate for symmetrical components, as well as asymmetrical components:

A. Symmetrical Components-

$$KW = \frac{\sqrt{3} \times V \times I \times \cos\theta}{1000}$$

B. Asymmetrical Components-

$$a = e^{j2\pi/3} = -\frac{1}{2} + j\frac{\sqrt{3}}{2}$$

$$I_{ab} = Y_l^{ab} V_{ab} = Y_l^{ab}(1 - a^2)V$$
$$I_{bc} = Y_l^{bc} V_{bc} = Y_l^{bc}(a^2 - a)V$$
$$I_{ca} = Y_l^{ca} V_{ca} = Y_l^{ca}(a - 1)V$$
$$I_a = I_{ab} - I_{ca}, I_b = I_{bc} - I_{ab}, I_c = I_{ca} - I_{bc}$$

$$\overset{0}{I} = (I_a + I_b + I_c)/\sqrt{3}$$
$$\overset{+}{I} = (I_a + aI_b + a^2 I_c)/\sqrt{3}$$
$$\overset{-}{I} = (I_a + a^2 I_b + aI_c)/\sqrt{3}$$

3- Voltage Drop contributing towards losses-

It is clear that voltage drop exists in all electrical distributions. In fact, major reason why people increase their supply voltage, or tap their transformer voltage higher than the desired voltage, is to basically compensate for the voltage drop in their distribution. As a result, a basic formula for such losses may be viewed as:

$$\%drop = \frac{KVA \times 1 \times (R\cos\theta + X\sin\theta)}{10(KW)^2}$$

4- I^2R losses-

I^2R losses(line losses), while other factors contribute to it, can be calculated discretely based on power factor:

$$\text{Ratio of } I^2R \text{ losses} = \frac{Loss@PF1}{Loss@PF2} = \frac{(PF2)^2}{(PF1)^2}$$

5- Reactive component of power distribution as applies to KW-

$$\text{Reduced energy} = \frac{R(KVAR)[2(KVA)\sin\theta - (KVAR)]8760}{1000(KW)^2}$$

6- Apparent and Reactive Power Improvement-

Apparent and Reactive Power Improvement will be considered, where customer is considered a primary supply voltage user. In other words, customer's electric meter is installed at Medium, or High voltage level. This generally applies to larger facilities/plants, or facilities with widely spread-out loads.

$$KVA_s = \left[1 - \frac{(KVAR)^2(\cos\theta)^2}{(KVA)^2} + \frac{(KVAR)\sin\theta}{(KVA_s)} - 1\right] KVA_s$$

7- Filtering harmonics, surges and transients-

The true RMS value that is wasted as a result of harmonics in a circuit, must be calculated incrementally. This means each $\mathbf{V}_{THD}$, $\mathbf{I}_{THD}$, and ultimately $\mathbf{P}_{THD}$ must be separately calculated for each submain, since such losses are cumulative. Some of the potential impact due to harmonics are:

- Overheating of transformers (K-Factor), and rotating equipment.
- Increased Hysteresis losses.
- Neutral overloading / unacceptable neutral-to-ground voltages.
- Distorted voltage and current waveforms, and excess wasted power.
- Erroneous register of electric meters.
- Wasted energy / higher electric bills - KWD & KWH.